Can you create mass from energy?

Bezverkhniy Volodymyr Dmytrovych.

Ukraine, e-mail: bezvold@ukr.net

According to A. Einstein [1]: “The mass of a body is a measure of the energy content in this body…”.

That is, if we have a certain amount of energy, then we inevitably get mass - the mass of a body is one of the forms of energy (Einstein).

To understand exactly how mass is created from energy, we will consider the proton and neutron, which are made up of three different quarks. And what is important: the proton quarks mass is only 1 % of the actual proton mass, and the neutron quarks mass is 1.3 % of the real neutron mass. In this example, we will see firsthand how nature creates a mass of compound particles like the proton and neutron.

But, first, let's recall the Bohr hydrogen atom, in which an electron in orbit moves with a speed of v = 2.188 * 10^6 m/s. Naturally, the mass of the electron in this case increases to the value m = 9.109626 * 10^(-31) kg.

$$m = m0 / (1 – v^2/c^2)^0.5$$

m0 – electron rest mass, m0 = 9.1093837 * 10^(-31) kg

What is especially important is that this relativistic addition of the electron mass (Δm) is exactly equal to the binding energy of the hydrogen atom (ionization potential) [2].

$$\Delta m = m - m0$$

$$E = \Delta m * c^2 = 2.1799567 * 10^(-18) J = 13.606 eV$$

Δm is the electron mass defect in the Bohr orbit.

This means that when a bound system of an electron and a proton (a hydrogen atom) is formed, the binding energy is released into the external environment (this is important!). Moreover, it is this energy that is literally “born” by a defect in the relativistic mass of an electron in the Bohr orbit.

Now consider a proton, which is made up of three different quarks. Let us assume that these quarks move at certain different speeds. According to the theory of relativity, the mass of all three quarks will increase.

Recall now that the addition of an electron mass in a hydrogen atom is released into the external environment in the form of binding energy.

But, quarks cannot exist outside the proton (unlike the electron and proton, which can exist separately - they can be removed from each other to infinity).

Therefore, the “binding energy” from the defect of the relativistic mass for quarks will be released into the “internal environment”, that is, inside the proton. Quarks cannot release energy into the external environment, since they do not exist in the external environment.

Consequently, all the energy generated by the movement of quarks will remain inside the proton.

And since “mass... is a measure of the energy content... in the body” [1], then the proton will have a certain mass according to the formula:

$$E = m(p) * c^2$$

$$m(p) = E / c^2$$

where E is the proton energy (rest energy),

m(p) is the rest mass of the proton,

c is the speed of light in vacuum.

Energy, like momentum, is an additive quantity (unlike mass). Therefore, the proton energy (E) will consist of three energies of the corresponding quarks:

$$E = E1 + E2 + E3$$

$$E1^2 = (p1 * c)^2 + (m1 * c^2)^2$$

$$E2^2 = (p2 * c)^2 + (m2 * c^2)^2$$

$$E3^2 = (p3 * c)^2 + (m3 * c^2)^2$$

where p, m, E1, E2, E3 are the momentum, rest mass, and energy of the corresponding quarks.

All of the above will be similar for the neutron, and in general for any system of bound particles like quarks (which cannot exist outside the bound system).

1. Einstein A. Ist die Trägheit eines Körpers von seinem Energieinhalt abhängig? Ann. Phys. 1905. Vol. 18 [323]. P. 639—641.

2. Bezverkhniy V. D. Bohr Model of the Atom, Mass Defect and Chemical Bond. SSRN Electronic Journal, 5 Dec 2022. https://dx.doi.org/10.2139/ssrn.4257744 https://vixra.org/abs/2210.0126